Italian science activities during SOS (Sustainable Observing Science) Arctic 2024

The activities that have been thought out and programmed take strongly into account on the one hand the limited timeframes that were available to plan and prepare them, and on the other the strong logistical constraints that the shipment and the conditions pose. Going beyond what is proposed will require careful analysis to identify appropriate technical solutions, but it would allow us to extract all the potential that the windsled platform could offer in terms of environmental monitoring on the Greenland Plateau.
The plan moves along two distinct lines, although potentially integrated in the future with the addition of further analyzes and measures:
A - snow sampling to study pollutants and prokaryotic populations
B - evaluation of background air pollution conditions in terms of aerosols and imported reactive gases such as ozone and NO2.

A – SNOW SAMPLES

Overall aim is to elucidate the role of melt dynamics and snow cover trends on the accumulation of pollutants and their potential release and transfer into the ecosystem and their impact on biodiversity. Snow is an effective matrix for recording atmospheric deposition and describing environmental transport drivers. This linkage with atmospheric chemistry allows us to reveal the sources, the long-range transport processes and the distribution of the emerging and legacy contaminants in the Greenland environment. For this reason, the occurrence of chemicals of emerging Arctic concern (CEACs) in snow will be evaluated. Our interest will be related to legacy (POPs) and emerging chemical contaminants (ECCs) and inorganic contaminants, which for their persistence and semi-volatility, may be found, even enriched, in the Arctic, far away from their initial emission sources, such as: selected legacy POPs, old and new brominated flame retardants (e.g. polybrominated diphenyl ethers and their metabolites, hexabromecyclododecanes), current use pesticides (e.g. chlorpyrifos, dachtal), perfluorinated compounds (e.g. PFOA, PFOS, and others), mercury, trace elements (TEs), and rare earth elements (REEs). Our aim is to contribute to the understanding of the processes affecting glacier ice, including snow cover, contamination, atmospheric interactions, and the impact of prokaryotic communities on glacier melt dynamics. In a global change scenario, melting ice and snow may remobilize the persistent organic pollutants (POPs) and microbes stored in these compartments back into the Greenland ecosystem. On the other hand, novel products and currently used chemicals are sources of contaminants of emerging concern, which are likely long-range transported and reflect the change of the human footprint on this environment.
Despite the known mechanisms of long-range transport to Arctic, ecosystem responses to climate change and pollution are mostly unknown; the direct and indirect responses induced by climate change can moderate or intensify the effects of environmental pollution and other human drivers.

Methods

1) Organic and inorganic contaminant analyses: A sampling and analytical protocol will be established for the field and laboratory work according to standard protocols and accredited methods including QA/QC. Analysis of legacy POPs (PCBs, DDT, etc.), priority and natural PAHs, ECCs will be done in snow, after extraction followed by GC-MS/MS and LC-MS/MS analysis. SPE

methods will be used to broaden the spectrum of analytes in liquid samples. Sample preparation will be carried out in controlled laboratories to avoid contamination (clean rooms from class 10000 to 100).

2) Mercury analysis: Total mercury in snow will be determined by ICP-MS, this will be confirmed by CV-AFS analysis. The mercury readily available fractionation will also be determined by CV-AFS after minimal sample treatment.

3) Microbiology analyses: Snow samples will be preliminary analyzed for the estimation of prokaryotic abundance and biomass by microscopic observations, including the enumeration of respiring cells. The prokaryotic community composition will be analyzed through next generation sequencing (NGS) of 16S ribosomal RNA gene amplicons. Pollutant-degrading bacteria will be isolated on growth media set up *ad hoc* for selected pollutants. Bacterial isolates will be phenotypically and genotypically characterized.

Moreover, snow samples will be analysed in laboratory for:

- Isotopes and inorganic chemical compounds: water major anions and cations will be analysed by ion chromatography and ICP-OES
- Analysis of legacy and emerging POPs will be done on water using SPE followed by GC-MS/MS and LC-MS/MS. Dissolved organic carbon (DOC) will be analysed by elemental analyser.
- Trace elements, including rare earth elements, potentially toxic elements and technology critical elements will be determined by ICP-MS.

Specific aims of the whole activity

- **Assessing the fate of contaminants in the abiotic compartments.** The presence and dynamics of inorganic and organic pollutants in snow will be evaluated by analyzing contaminants like POPs and mercury, alongside rare earth element indicators, to understand pollution distribution and its evolution, particularly through snowmelt runoff.
- **Evaluating contamination fluxes and amplification processes in snowmelt run-off.** This involves examining how pollutants are transported and possibly concentrated during snow melting, highlighting the consequent possible amplification processes in order to enhance understanding of the extent of the seasonal contaminant release and bioavailability in the ecosystem.
- **Disentangle the role of microbial life on pollutant distribution and fate.** Investigation of the relationships between microorganisms and pollutants, focusing on the microbial community fractions (both total and cultivable) able to tolerate and/or degrade pollutants. Dynamics of natural microbial communities: to assess microbial community structure and functions at spatial scale in relation to contamination.

Research Team devoted to line A competencies/expertises

CNR-ISP team has a long and acknowledged experience in Antarctic and Arctic Research and has already worked in different polar regions in the framework of several research projects. Therefore, they have the expertise to manage the project, the field work and laboratory activities, each of

them being able to provide expert support to the proposed research activity. The Institute of Polar Sciences (CNR-ISP) will contribute to the research activities through the staff located in the branches of the institute in Venice, Bologna and Messina. The activities will therefore include the analytical determinations of selected organic and inorganic contaminants in the different environmental matrices, and the observation of the effects on the microbiome. CNR-ISP Bologna and Venice has developed considerable expertise in the field of environmental chemistry and ecotoxicology, with particular regard on the monitoring of the occurrence, distribution, persistence and fate of organic micro-pollutants of environmental concern in different compartments including the effects on biota. Analytical instrumentation and facilities are available at the laboratories of the CNR-ISP. CNR-ISP is an expert group in chemical analysis and sampling of environmental matrices. They have access to snow, sea ice and air sampling facilities as well as the analytical instrumentation necessary for the successful implementation of the project. CNR-ISP Messina has a long experience in studying the microbial compartment in polar areas. Research efforts are mainly addressed to the analysis of microbial abundance, diversity and functions in relation to environmental conditions, including those subjected to modifications deriving from anthropogenic influence, by adopting both classical and advanced biomolecular techniques.

B - LOW-COST TECHNOLOGY FOR AIR QUALITY MONITORING

The activities are in line with the PIONEER project aims to develop Low-Cost Sensor (LCS) wireless networks technologies for environmental monitoring of remote areas of the Planet, known as Climate Sentinels. This initiative is particularly crucial for studying inaccessible regions and provides a real-world platform to validate environmental models related to emissions and to grasp the spatial variations in pollution levels across different geographies.
The project involves a strategic partnership with the Inuit Windsled Project, which is crucial for the field implementation of the developed technologies. This collaboration facilitates the deployment of a cutting-edge portable sensing apparatus designed to monitor key atmospheric components. The core of this collaboration is the development of an advanced portable sensing apparatus capable of measuring critical atmospheric pollutants such as ozone, nitrogen dioxide, and particulate matter. This technology will be deployed on the Inuit Windsled, an eco-friendly transportation method tailored to the harsh conditions of Greenland.
The portable sensing apparatus will be tested in Greenland during Summer 2024. This period is critical for capturing the dynamics of atmospheric components providing valuable insights into the background level of pollutants in polar regions.

Expected Outcomes:

- Validation of Technology: The data collected will be instrumental in validating and refining the sensing device.
- Enhanced Understanding of Pollution Patterns: The project aims to delineate the spatial distribution of key pollutants, offering insights into their behavior and impact in remote polar environments.

Significance:
The Inuit Windsled Project exemplifies a unique intersection of indigenous knowledge and modern scientific inquiry, leveraging sustainable practices to advance research in some of the most isolated

parts of the world. This project not only underscores the importance of innovative, cost-effective technology in environmental science but also highlights the role of international collaboration in tackling global challenges.

Project Link: https://cordis.europa.eu/project/id/844526
Reference: https://amt.copernicus.org/articles/14/6005/2021/
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